RENEWABLE DIESEL PROJECT

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NBC Strategic Partnerships Workshop

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Program Goals

All projects meet one or more of the following:

- **Reduce the cost of renewable diesel**
- **Expand the supply**
- **Reduce barriers to expanded use**

Budget Status

- **FY 1997 - 2001 Annual Budget = $750,000**
- **FY 2002 + ?**

Renewable Diesel Fuels

- **Biodiesel**
  - Program R&D focus since 1977
- **Fischer Tropsch Fuels**
  - Evaluation of wax producing facilities with satellite cracking facilities
- **DME (di methyl ether)**
  - evaluation of propane blending and/or replacement potential
- **Ethanol-diesel blends**
  - technical support to other programs
- **Other (pyrolysis oils, DMM, DEE, alcohols….)**
  - technical evaluation

Biodiesel Project

- **Priority focus**
  - Feedstock expansion and feedstock cost minimization
  - Goals
    - 6-10 billion gallons of oil at 10 cents/lb
    - Expanding markets for meal worth 15 cents/lb or more
- **All other projects**
  - Improve technology and reduce production costs
  - Reduce market barriers
  - Expand outreach

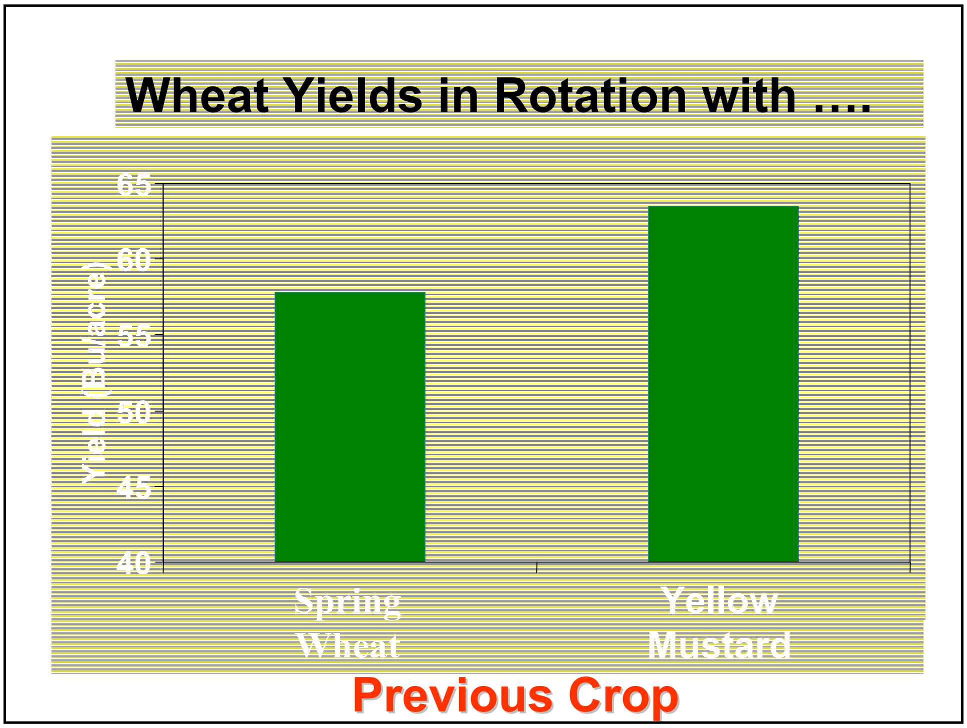
Biodiesel Production Costs

Capacity mil gal/yr	Feedstock type	Feedstock ¢/lb	FFA %	Total Cost Biodiesel $/gal ± 0.10
10	Soy	25	<1	2.36
10	Soy	17	<1	1.66
10	Yellow grease	10	<10	1.12
10	Trap grease	<5	>50	0.76
10	Mustard	10	<2	1.05

Batch processing, wet salty glycerin @ 15 ¢/lb, full capacity costs, ROR=15%

Brassica Crops

- Meal has Allelopathic compounds
- Broad-leaf crop with high biomass
- Large tap root
- Low production costs, low inputs
- Good yields in dry land farming conditions
- Yields optimization untapped potential
- Seed oils 25% to 40%
- Oils have good biodiesel qualities
- Excellent rotational benefits
- Planted and harvested with wheat equipment



Glucosinolates in *Brassica*

Species	Roots	Leaves	Seed meal
	----------- μmol/g ----------		
B. napus	5.3	8.6	99.4
B. rapa	4.6	7.4	93.0
B. juncea	10.2	18.1	216.4
S. alba	12.3	15.3	244.1

Why Organic Pesticides

- Sustainable
- Internationally competitive
- Environmentally friendly
- Fewer commercial chemicals available
- High value market
- Expanding markets worldwide

Glucosinolates in *Brassica*

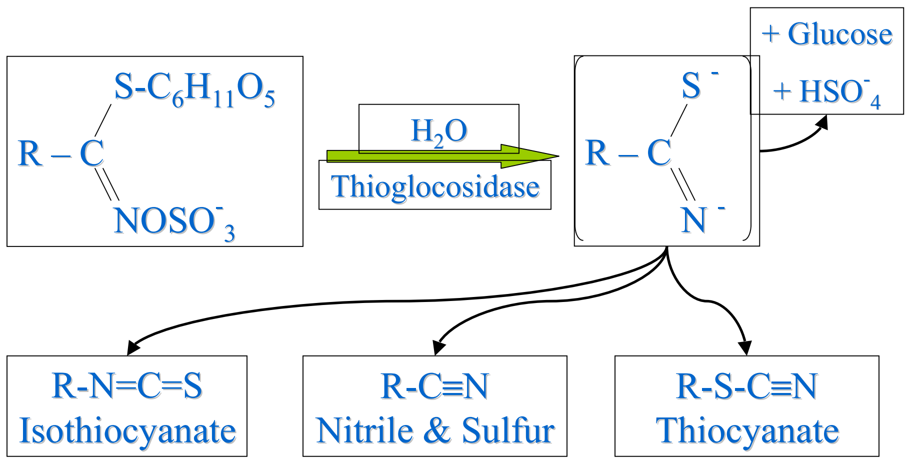
- Isopropyl
- Allyl
- 3-butenyl
- 4-pentenyl
- 2-OH-3-butenyl
- 3-OH-4-pentenyl
- OH benzyl
- phenylethyl
- 3 methylindolyl
- 4-OH-3 methylindolyl

Allyls have fungicide value
Butenyls have herbicide value
Pentenyls have insecticide value

Little is known about other 200 glucosinolates

Some glucosinolates have been shown to be potent anit-carcinogenic compounds in laboratory animals.

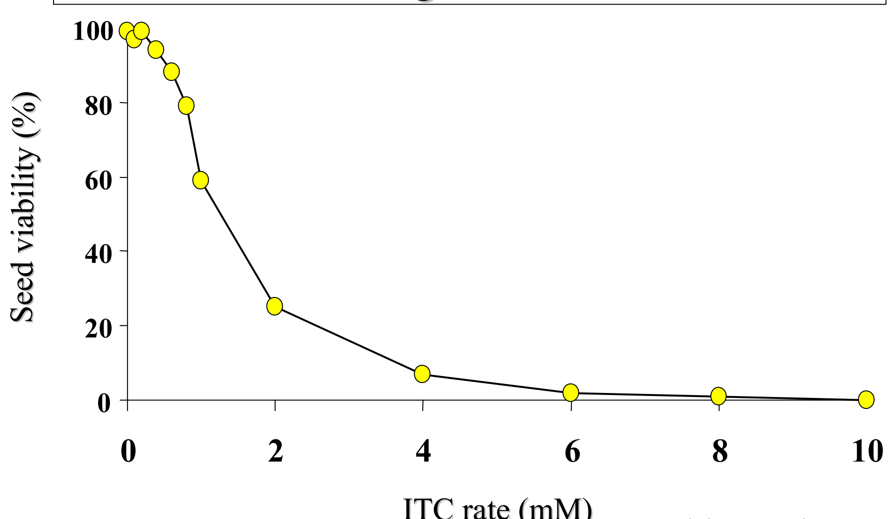
Glucosinolate Breakdown



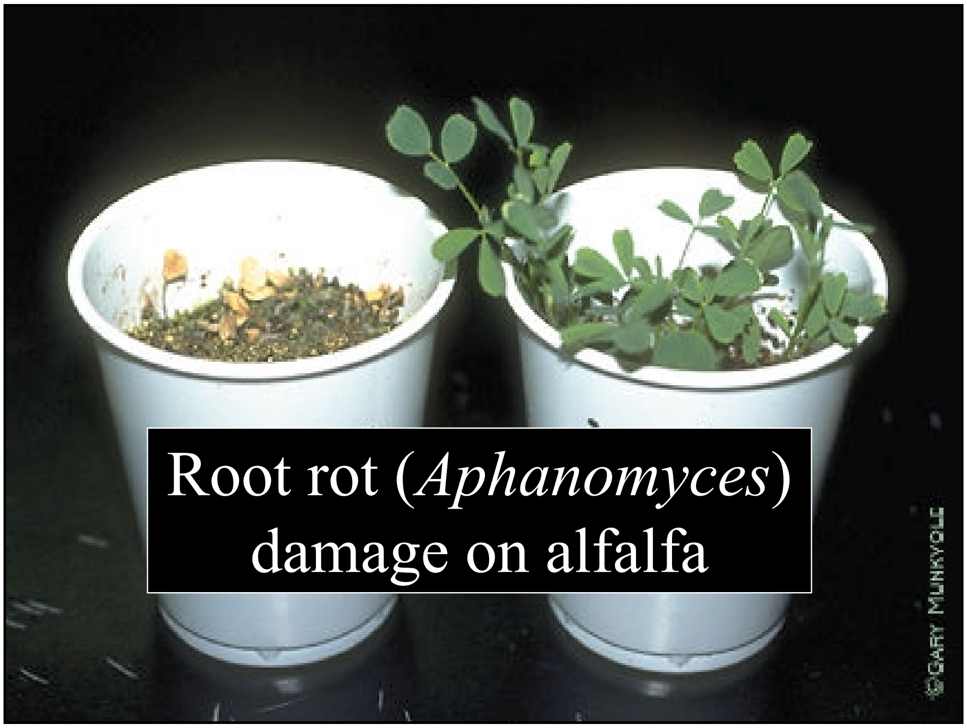
- Many US crops require chemical soil fumigation
- Fumigation costs in excess of $3500 per acre
- EPA made methyl bromide illegal in 2000
- No commercially viable substitutes widespread

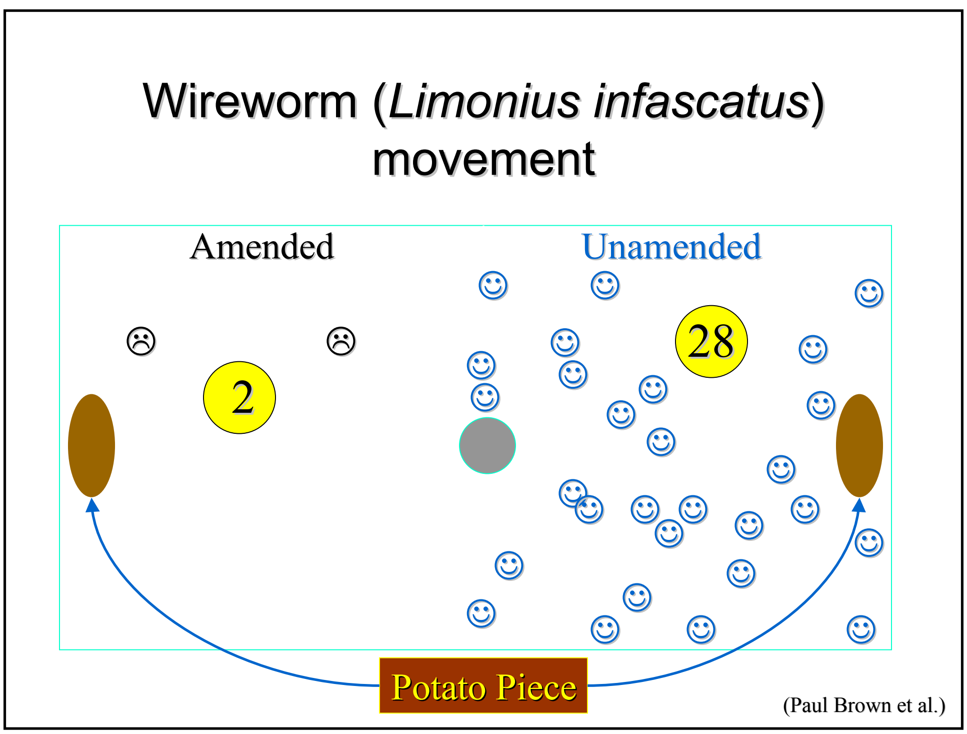
Methyl Bromide Soil Fumigation

Effect of isothiocyanate on of crab grass

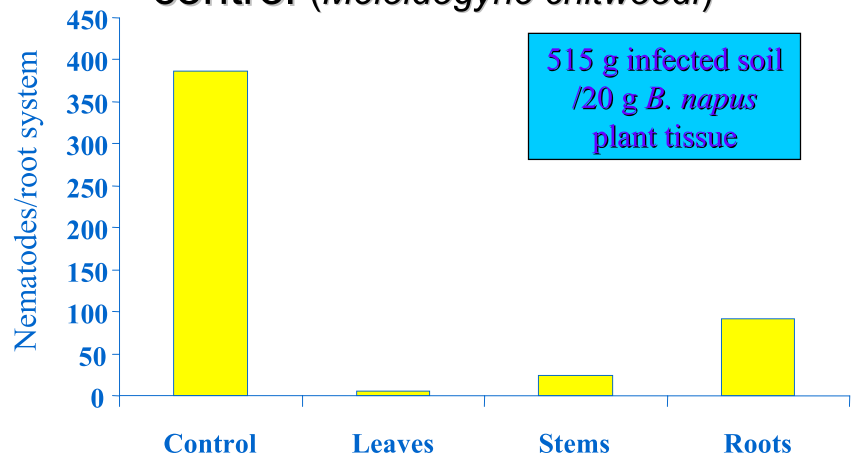


Teasdale & Taylorson, 1986

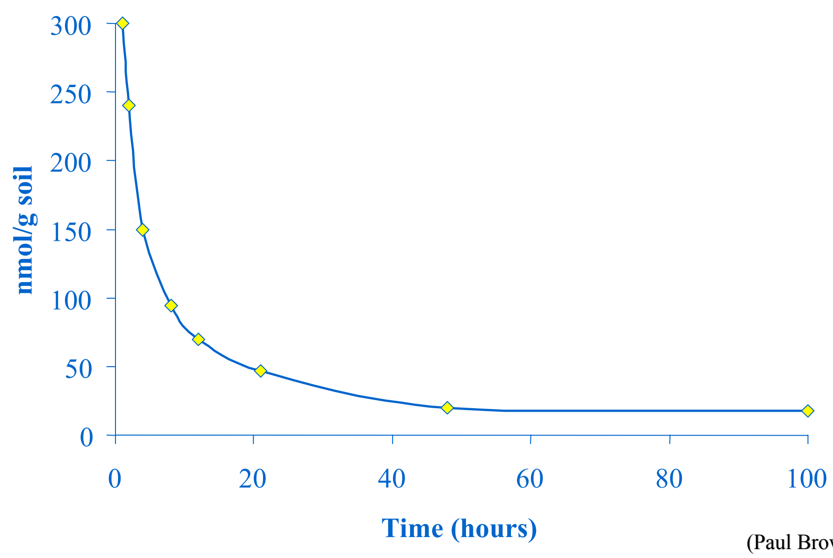

Root rot (*Aphanomyces*)
damage on alfalfa
©GARY MUNKVOLD


Wireworm (*Limonius infascatus*)
movement
Amended
Unamended
2
28
Potato Piece
(Paul Brown et al.)

Columbian root-knot nematode control (*Meloidogyne chitwoodi*)



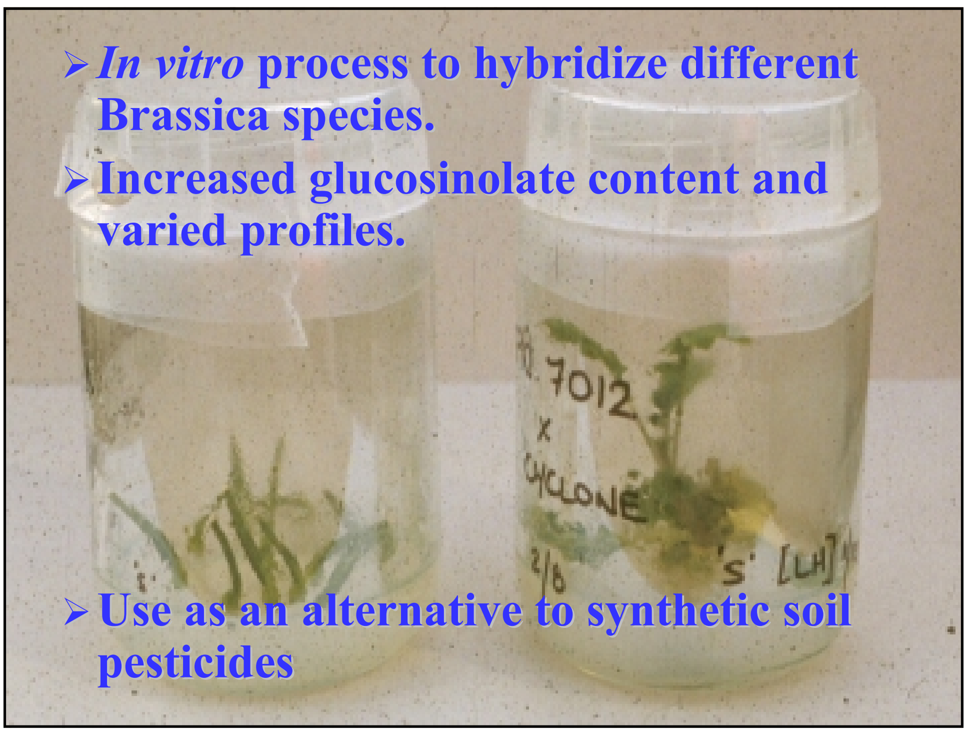
Isothiocyanates in Soil



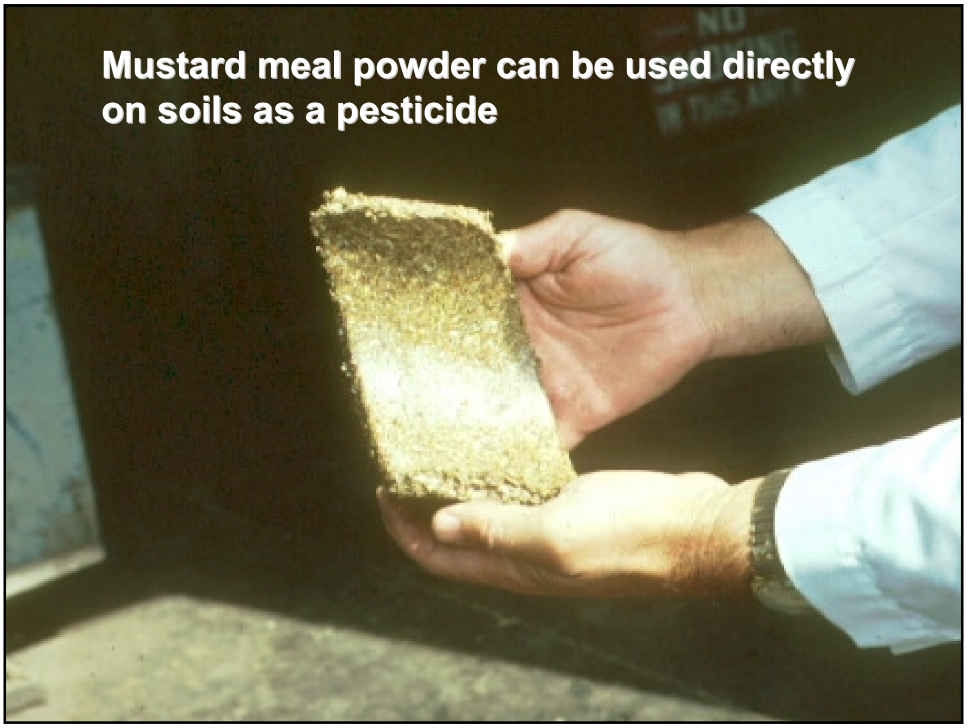
(Paul Brown et al.)

What do we have so far?

- Glucosinolates concentrate in the meal
- Glucosinolate breakdown products kill agricultural pests
- Different *Brassica* species produce different glucosinolates
- Byproducts from specific glucosinolates have unique impacts on specific agricultural pests



- ***In vitro*** **process to hybridize different Brassica species.**
- **Increased glucosinolate content and varied profiles.**
- **Use as an alternative to synthetic soil pesticides**


Mustard meal powder can be used directly on soils as a pesticide


Byproduct mustard oils have little or no other commercial value except for biodiesel if pesticides are major product line

Mustard Project

Develop varieties of mustard seed with:
- 25 - 40% oil content (closer to 25%)
- Oil with 90% monosaturate content
- Oil with eurcic acid > 2% and <20%
  - Inedible and not a animal feed oil, no high industrial value
- 2 tons seed per acre or more
- Low inputs (e.g., seed production costs ~ 7 cents/lb)
- Meal contains >500 μmoles/gm specific types of glucosinolates
  - Fungicide variety
  - Herbicide variety
  - Pesticide variety (nematode, wire worms, cut worms…)
- Meal value 15 cents/lb or higher
- Meal is cost competitive with commercial pesticide brands and equally effective at control

Fatty Acid Profiles

Species	Fatty Acid Profile						
	16:0	18:0	18:1	18:2	18:3	20:1	22:1
Canola	**4.7**	**1.9**	**65.4**	**19.3**	**7.3**	**1.1**	**0.0**
Rapeseed	**2.5**	**0.7**	**11.4**	**10.6**	**9.1**	**5.4**	**55.7**
H. mustard 1	**4.1**	**3.1**	**40.3**	**7.8**	**1.7**	**6.4**	**25.5**
H. mustard 2	**2.5**	**2.4**	**56.3**	**5.5**	**2.2**	**4.5**	**20.7**

Seed Meal Glucosinolate Content

Species	Total Gluc's	% Humus
B. napus 'Humus'	99.4	100.0
B. nigra x *B. rapa*	516.1	519.2
S. alba x *B. napus*	451.0	453.7

Glucosinolate Profile

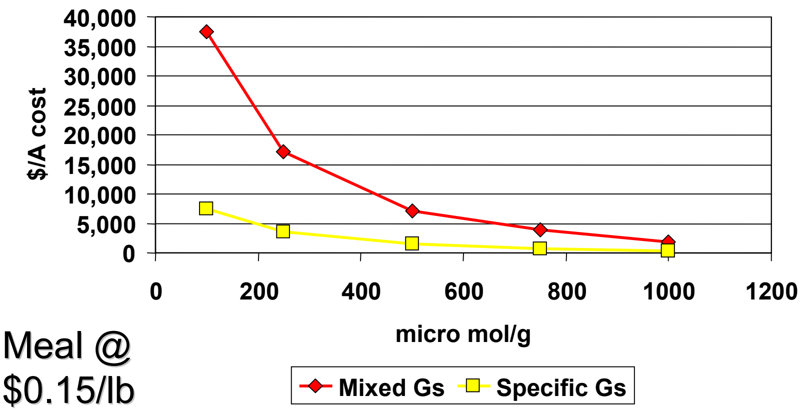
Glucosinolate Type	*B. napus* Humus	*B. nigra* x *B. rapa*	*S. alba* x *B. napus*
Allyl	0.0	205.0	0.0
3-butenyl	13.2	197.8	0.0
4-pentenyl	43.7	48.7	1.8
2-OH-3-butenyl	30.5	61.6	19.6
OH-benzyl	0.0	0.0	290.6
Phenylethyl	5.3	1.4	1.8
3-indolyimethyl	6.6	Trace	120.9
4OH3-indoylmethyl	Trace	1.4	16.1

Drive Down Application Rates

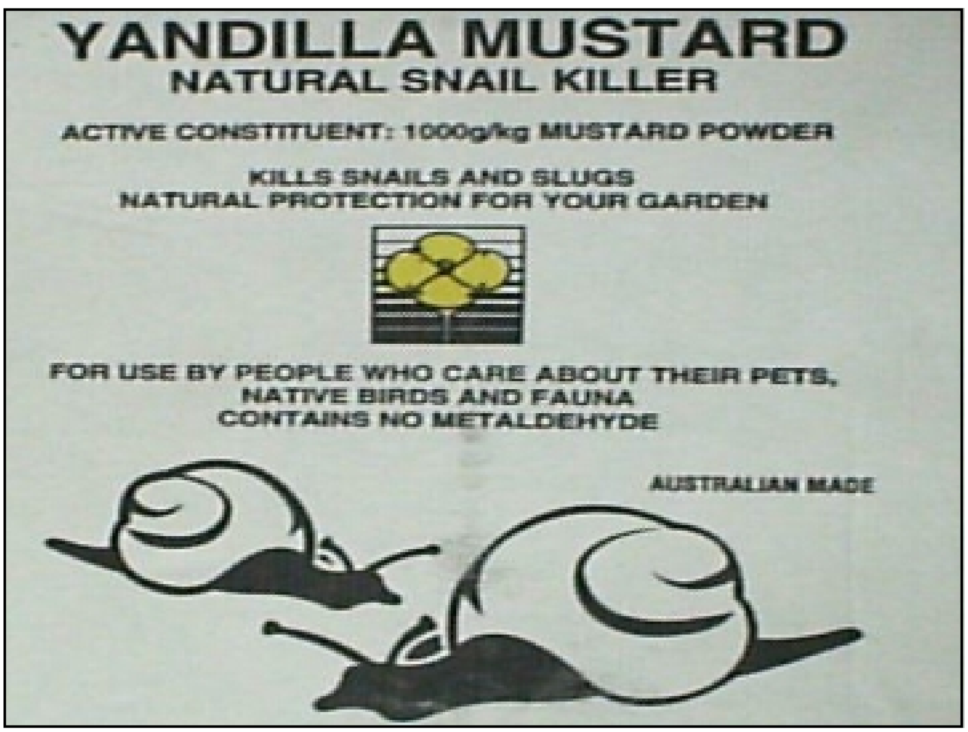
Species	Seed meal -- µmol/g --	25.0 g/m^2 - ton/acre -
B. napus	99.4	124.7
B. juncea	216.4	57.3
S. alba	244.1	57.3
B. rapa x *B. nigra*	516.1	24.0
S. alba x *B. napus*	451.0	27.5

Assume 19% of glucsinolate goes to isothiocyanate.

Glucosinolate Content vs Cost



Meal @
$0.15/lb



Isothiocyanate Extraction

Out-Year Mustard R&D

- **2001**
  - **Multi-state hybrid trials in PNW with 60 varieties**
  - **Agronomics, rotation benefits, input variation**
  - **Glucosinolate optimization, fatty acid optimization**
  - **Market analysis**
  - **Registration analysis**
- **2002**
  - **pesticide demonstration trials with industrial partners**
  - **pesticide registration R&D**
  - **Kansas and Georgia regional breeding trials**
  - **breeding work continues for optimization**

Reduce Biodiesel Costs

- Biodiesel Technology Analysis
  - Soy and yellow grease feedstocks
  - 3, 10, 30 mil gal/yr scales
  - baseline info on technology and costs
- Waste Grease Composition and Pretreatment
  - 45 samples analyzed, FFA range from 40% to 100%
  - Other impurities minor, good conversion potential
- Trap Grease to Biodiesel Feasibility and Demonstration
  - Demonstrate 99% conversion of 60-90% FFA feedstocks to ASTM quality biodiesel at reasonable cost
  - Consortium of regulators, sewage treatment plants, biodiesel producer, and trap grease collectors.

Barriers Projects

- NOx Project
  - Identify root cause of higher NOx emissions
    - polyunsaturated fatty acids
  - Identify specific pathways of NOx in combustion chemistry
    - 1 degree timing advance due to different fuel compression characteristics
    - Other factors underway
  - Identify additives that prevent NOx increase in biodiesel
    - 1% DTBP makes B20 NOx neutral with petro diesel
    - other additives being tested

Barriers Projects

- Urban Air Quality Model Data
  - B20 and B100 data for Mobile 5/6, OTAG, CARB models
  - SIP analysis of B20 options (PM, CO, Ozone)
- Oxidative Stability Test Methods
  - Recommended 3 test methods for further development
  - Refine test methods for B20 and B100
  - conduct round robin
  - ASTM inclusion
- Life Cycle Analysis of Grease and Fat Biodiesel
  - Partnership with Fats and Protein Research Foundation

New Markets R&D

- Heating Oil Technology Assessment
  - Evaluate the technical parameters for biodiesel blends with heating oil in residential and commercial boilers
  - Partners: NYSERDA, NBB, Griffin Industries, Brookhaven
- Warwick School Dist. Demonstration
  - Evaluate 3 biodiesel heating oil blends (10%, 15%, 20%) in three public school buildings boilers over 12 months
  - Partners: Global Companies, Brennan Oil, Rhode Island Energy Office, Warwick School District, Advanced Fuel Solutions, World Energy
- Locomotive Emissions from B20
  - raw data completed, report expected this year
  - Partners: CSX railroad, CARB, AAR

Outreach and Education

- Production Accreditation
  - Develop 4 college level classes on biodiesel
    - Introduction to Biodiesel
    - Biodiesel Analytical Methods
    - Biodiesel Technology
    - Biodiesel Business Management
- Petroleum Infrastructure
  - Outreach with petroleum distribution industry (PMAA, …)
  - Analysis of integration costs
  - Heating oil industry outreach
- Annual R&D Mtg (Feb, 2001)
- 5-6 Regional Workshops (late FY 2001)